Fast Wavelength Switching Lasers Using Two-section Slotted FP Structures

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Abstract *Fast wavelength switching of a two-section slotted FP laser structure is presented. The slot design enables operation at 5 discrete wavelength channels spaced by 10 nm by tuning one section of the device. These wavelengths operate with SMSR in excess of 35 dB, and a switching time of approximately 1ns is demonstrated.*

Introduction

Wavelength tunable lasers are becoming a mainstream component in photonic networks. In addition to their role in inventory reduction, these tunable devices may also be used for developing network architectures that employ wavelength packet routing [i,ii] for extremely efficient bandwidth utilization in WDM systems. In these networks, optical packets at different wavelengths are generated by a fast tunable laser in conjunction with an external modulator. The packets can then be routed to specific nodes in the network by using simple optical filtering techniques.

The design of the wavelength packet-switched WDM networks will be heavily dependent on the characteristics of the tunable lasers such as tuning range, side-mode suppression ratio (SMSR), output power, and speed at which the device can switch from one wavelength to another. The most suitable lasers for use in wavelength packet-switched systems are normally electronically tunable devices [iii] such as the Sample Grating distributed Bragg reflector structure (SG-DBR) [iv]. These devices can achieve tuning ranges in excess of 60 nm, SMSR's exceeding 40 dB, output powers above 10 dBm, and switching times in the order of 20 ns. The main disadvantage of these devices is the complexity of fabrication, which can typically require multiple epitaxial stages that require high tolerance steps.

The work carried out in this paper investigates the use of a two section slotted FP structure for developing a wavelength tunable laser diode. These devices are easier to fabricate than traditional electronically tunable devices described above as they are based on single epitaxial step, and not multiple epitaxial stages that require high tolerance steps such as grating formation (as is the case for SG-DBR devices). Our results show that the initial devices fabricated can discretely tune over a range of 40 nm by varying the current applied to one section, and achieve an SMSR of greater than 35 dB for these wavelength channels. In this work we demonstrate the ability of such a device to switch between channels on a time scale of around 1ns.

Tunable laser design using slotted FP structure

To fabricate the devices used in this work, we initially fabricated conventional 3 μm wide ridge waveguide lasers based on commercially available material. During the fabrication a series of slots are introduced into the ridge that act as sites of internal reflections [v]. The slots are etched to a depth which just penetrates the top of the upper waveguide resulting in an internal reflectance of ~ 1% at each slot. The structure of the device studied in this work is shown in Figure 1.

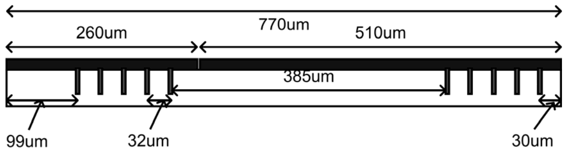

Figure 1: Device structure

Due to the relatively large reflectivity from the individual slots, a number of sub-cavities are formed. The 35 μm slot separation results in a free spectral range of approximately 10 nm which sets the supermode spacing. A second sub-cavity is formed between the two sets of slots and this cavity sets the dominant Fabry Perot mode spacing in the laser spectrum. Finally, sub-cavities are formed between the slots and the uncoated facets. As the different sections of the laser are differentially driven, the local refractive index is changed due to an increase in carrier density associated with incomplete carrier clamping, a change in the local gain resulting in a change in index through the linewidth enhancement factor and due to current-induced heating. The latter induces a Δn of 5×10^{-5} per milli-amp under CW conditions. These index changes result in a change in the resonant conditions favoring one of the supermodes.

Experimental Setup And Results

The initial experimental analysis on the devices described above involved static characterization.

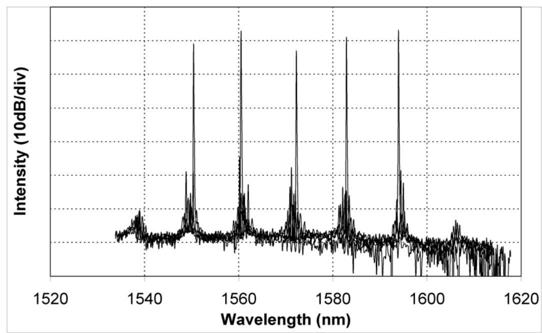

Figure. 2 Combined optical spectra from the slotted FP laser at five different operating points with SMSR > 35dB

Figure 2 shows five different optical spectra from the device overlaid on top of each other. The device has two sections, and by setting the current applied to one section at 88 mA, and varying the DC current applied to the second section, single mode operation with high SMSR is available over a range of 40 nm, with a channel spacing of 10 nm (corresponding to the supermodes of the device).

As stated above, the switching speed of a tunable laser is one of the most important features for WDM optical packet switching. In order to test the switching speed of the device the experimental set up shown in figure 3 was used. One section of the laser is driven by a constant DC current of 88mA, and the other is driven by a square wave signal at a frequency of 50 MHz generated by an Anritsu Pulse Pattern Generator (PPG). The square wave signal shifts the current applied to the second section of the laser between 120 mA and 140 mA, which causes the laser to switch from 1560.5 nm (referred to as 'channel 1' henceforth) to 1593.9 nm (referred to as 'channel 2' henceforth) every 20 ns.

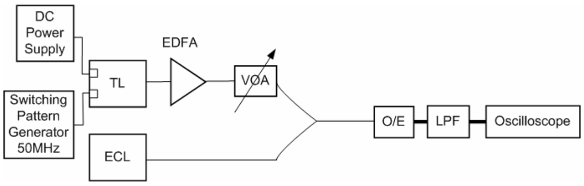

Figure 3. Experimental configuration used to determine switching time of TL module.

To accurately measure how long it takes for the laser to switch wavelength, we use a heterodyne technique that involves the use of an external cavity laser (ECL) set to a frequency 1 GHz away from channel 1 of the slotted laser. When the optical output from the slotted laser and the ECL are coupled together and sent to a photodetector, a beating signal is generated between the optical carriers at the frequency difference between them. An optical amplifier and variable attenuator are used to ensure that the power from the two-section device and the ECL are equalized before the detector. When the laser is switched to channel 1 (which lies 1 GHz from the emission frequency of the ECL) a 1 GHz signal will be generated which can be viewed on the oscilloscope. When the laser is switched to channel 2, the beat signal generated would be at a frequency of around 4.2 THz, but this is far beyond the bandwidth of the detector and scope, so a DC signal is generated. By placing a 1.87 GHz low pass electrical filter after the photodetector, we can determine how long it takes the laser to get within 1.87 GHz of the target frequency when it is switching from channel 2 to channel 1. Figure 4 presents the detected electrical signal as the laser is switching between channels 1 channel 2 at a rate of 50 MHz. The DC component corresponds to the time that the laser is operating on channel 2, and the modulated portion corresponds to the time the laser is operating on channel 1. As the optical power from the laser is slightly greater on channel 1 than on channel 2, the DC level when the laser is operating on channel 2 is below half the level of the modulated signal. By investigation of the time when the laser switched from channel 2 to channel 1, we can see that the laser has completed it's switch to within 1.87 GHz of it target wavelength after about 1.3 ns. Unlike SG-DBR and GCSR tunable lasers that have passive tuning sections, these two section slotted FP lasers have active sections. This ensures that the carrier lifetimes that may affect switching speed are limited by stimulated carrier lifetimes, and not spontaneous lifetimes as with SG-DBR and GCSR. It is thus possible to achieve very fast switching times.

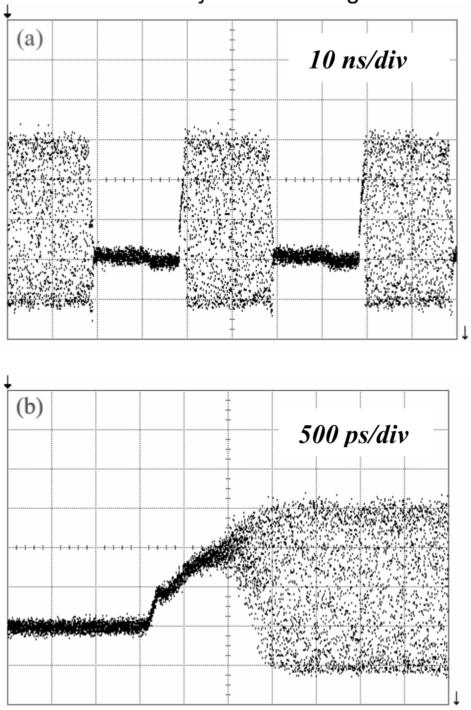

Figure 4. Beating signal generated when output of switching laser is mixed with ECL signal 1 GHz away from channel 1 of slotted laser with (a) 10 ns/div (b) 500 ps/div.

Conclusions

We have presented a novel design of a wavelength tunable laser based on a two-section slotted FP structure. These devices are easier to fabricate than currently commercial electronically tunable lasers because they are based on a single epitaxial step. Our results show that these initial devices can operate with SMSR's in excess of 35nm and can access 5 wavelength channels with 10 nm spacing by tuning the current to one section. We have also demonstrated that these devices are capable of switching between two wavelengths, to within 2 GHz of the desired channel, on a timescale of 1 ns.

References

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